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AND
CONSTRUCTIONAL ENGINEERING

INCLUDING PRESTRESSED CONCRETE

AUGUST 1959 **VOL. LIV. NO. 8**

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Volume LIV, No. 8. LONDON, AUGUST, 1959.

EDITORIAL NOTES

Aids to Design.

THE calculations required when designing a structural member can be tedious and, if worked directly from first principles or from formulæ based on first principles, may take much time. It is imperative that calculations made by a student should be based on fundamentals so that the underlying principles are fully understood and not concealed by short-cut methods. But it is permissible for a more experienced designer to adopt means whereby the work, and therefore the cost, of calculating can be reduced. This is even desirable, because the designer is then freer to concentrate on the engineering aspect of the design and his judgment is not so likely to be dulled by excessive arithmetical processes. Arithmetical aids which enable several designs to be prepared with the least labour and in the shortest time are a necessity when comparative schemes are being prepared.

Aids to design, apart from apparatus such as slide-rules and calculating machines, are generally in the form of tables, graphs, and nomograms, from which the result of an arithmetical operation involving one or more variable factors can be determined at sight or at least by one simple manipulation. An aid is justified if it is quicker to apply the aid than to calculate the result from the basic formula. Even if it is no quicker, it may be claimed that the use of an aid, however simple, may avoid arithmetical errors.

The advantage of a table is that the numerical value of the required result is seen at a glance so long as the numerical values of the known variable factor or factors upon which the result depend coincide with those in the table. Otherwise interpolation is necessary. When two variable factors only are concerned and the relation between the two is linear, accurate interpolation is generally easy. If three variable factors are concerned, in which case an aid is particularly useful, interpolation between four results has to be effected and this is not always easy, especially if the variations are not linear. The simplest form of table comprises two columns, such that the equivalent of a known quantity in one column is immediately read in the adjoining column. A table comprising several columns giving the results of a computation involving two variable factors is more complex. Such a table can be used in reverse, that is if the result and one of the variable factors are known the other variable factor can be established. Interpolation may be difficult since it is generally practicable to give only one of the variable factors in small increments. One test of the adequacy of a table is whether the

intervals between the factors tabulated are such that linear interpolation gives a result that is sufficiently accurate. When there are three variable factors, combined tabulation of the results may be impracticable unless there are few possible values of two of the variable factors. In effect, such a table is a series of separate tables. If only one of the variable factors can be presented in a few increments, tabulation is reasonable only by preparing a separate table for each increment of this factor.

Graphs in which the results are read at the point where an ordinate, representing one of the variable factors, intersects a curved line have some of the limitations of tables. They have, however, the great advantage that interpolation can be done visually whether it be linear or to a higher degree, and whether the relation be between two or three variable factors. Extrapolation to a moderate degree can also be done when using graphs, but caution is necessary in doing so. Graphs are more easily prepared than tables as only a few results need be calculated to establish a curve, whereas every result must be calculated accurately for inclusion in a table. A graph also enables the effect of variation in one factor to be seen at a glance and an assessment of whether or not such variation is material. On the other hand, graphs do not present the numerical result quite as plainly as a table, but this objection is generally outweighed by other advantages, such as the practicability of plotting more clearly the results of two variables by means of several curves on one diagram. By superimposing one series of curves upon another it is possible to deal with three variables on the same diagram.

To ascertain the result arising from two variable factors, nomographic charts, commonly called nomograms, are suitable and may combine the accuracy of a table with the versatility of a graph. Interpolation is generally automatic. In its simplest form a nomogram comprises three parallel scales one of which represents the result and two represent the variable factors. A straight-edge laid across the scales, so that it intersects two scales at the values of the known variable factors, enables the result to be read on the third scale at the point where it is intersected by the straight-edge. The construction of nomograms is described elsewhere in this number, and it is shown that this form of aid can be prepared to give the result of four or even more variable factors in a form much more concise than is possible with graphs or tables. It is not essential that the scales should be rectilinear, and nomograms with curved scales have proved particularly useful for designing frames. In this instance the alternative to the use of nomograms is to substitute the values of the known variable factors in formulæ and then to perform the subsequent arithmetical operations, which usually takes longer.

The use of nomograms and the reading of tables and graphs are, to different degrees, mechanical operations, but it can be claimed that the use of these aids to design needs as much intelligence as the substitution of arithmetical values in formulæ. The results obtained may not be quite as accurate as those derived from formulæ, but the risk of error, which is inseparable from all arithmetical processes, is avoided. Also the time saved by the use of aids appeals to a busy designer and consequently to those responsible for remunerating the designer. It is important, however, that no use should be made of an aid to design unless the user has taken the trouble to examine and understand the basis, and therefore the limitations, of the diagram or table.

The Construction of Nomograms.

By W. E. SCRIVEN, B.Sc.(Eng.).

THE construction of nomographic charts, or nomograms, to represent the theoretical or empirical relations between variables can sometimes be laborious, but is usually well worth while. Any degree of accuracy can be obtained, and the need to remember formulæ and the limits within which they apply is obviated.

Charts from Empirical Data.

Nomographic charts from empirical data are obtained by graphical construction. The only requirement is that the data when plotted must form a set of straight lines or a true family of curves. The procedure is then as shown in *Fig.* 1. Each straight line is represented by one of the crosses, and each cross is obtained by plotting any two points such as those shown. If the data were such that all the lines were parallel, the crosses would be in one straight line. Interpolation between the crosses is permissible provided that the positions of the lines are dependent on only one variable.

It is evident, therefore, that any data which can be plotted in a linear manner may be represented by nomographic charts. Three methods are available for transforming a set of curves into a set of straight lines. The best known is that in which one variable is plotted against a suitable function of the other. For example, exponential curves can usually be made linear by plotting one variable against the logarithm of the other. The selection of suitable functions is a matter of experience; in some cases arithmetical difference tests must be resorted to; this, however, is a problem in curve-fitting and is not considered here. The other two methods are simpler and do not require any intuitive mathematical skill. They are known as single-scale and double-scale distortion, the object being the rearrangement of the divisions on the axes of the graph so as to produce a straight line. In *Fig.* 2 is an example of single-scale distortion, together with the final nomogram showing the relation between the age of dense concrete (days), the temperature at which the concrete was cured (deg. Fahr.) and the percentage of the compressive strength of the concrete at 28 days when cured at 64 deg. Fahr. In *Fig.* 3 is an example of double-scale distortion, the intervals of scale, p and q, being chosen to suit the lengths of the scales required.

It is to be noted that if the original curves do not form a family the distorted scales will not completely straighten all the curves. A simple test, known as the Bilinearity Condition, is shown in *Fig.* 4; the condition is that criss-cross lines drawn between upper and lower curves must intersect on the middle curve.

Charts from Mathematical Equations.

THEORY.—The theory of the analytical construction of nomographic charts is simple, but if there are more than four variables the calculations may become involved.

The condition for a straight line to intersect three curves at (x_a, y_a), (x_b, y_b), (x_c, y_c) is

$$\frac{y_b - y_a}{x_b - x_a} = \frac{y_c - y_a}{x_c - x_a}$$

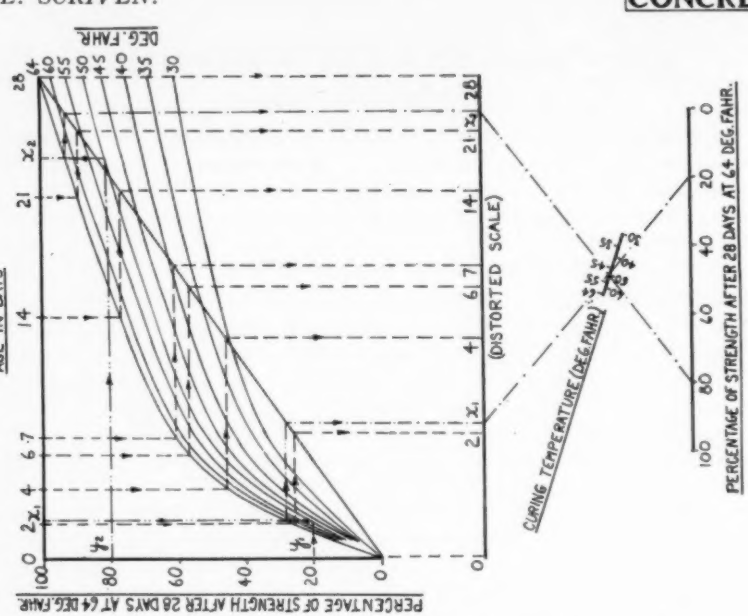
AGE IN DAYS
DEG. FAHR.
PERCENTAGE OF STRENGTH AFTER 28 DAYS AT 64 DEG. FAHR.
(DISTORTED SCALE)
CURING TEMPERATURE (DEG. FAHR.)
PERCENTAGE OF STRENGTH AFTER 28 DAYS AT 64 DEG. FAHR.

Fig. 2.

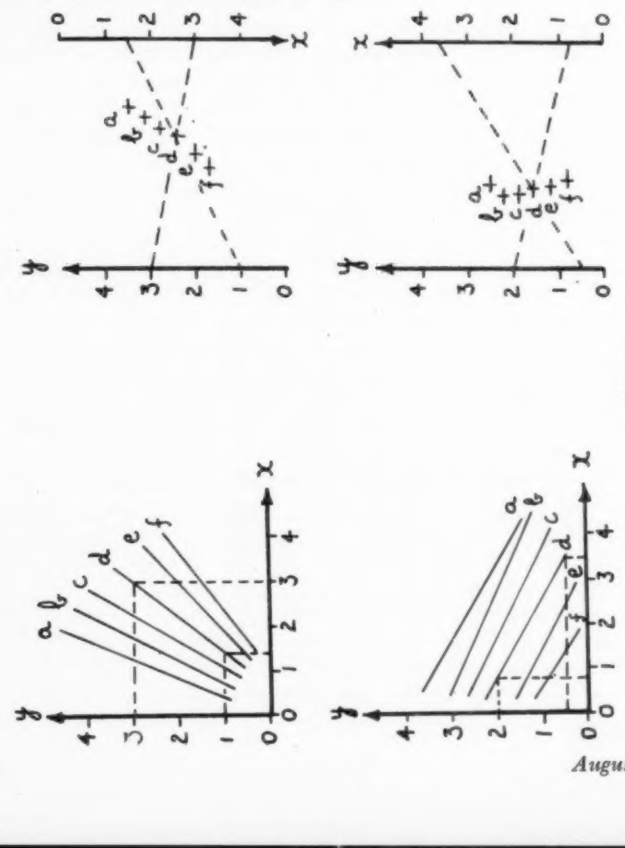

Fig. 1.

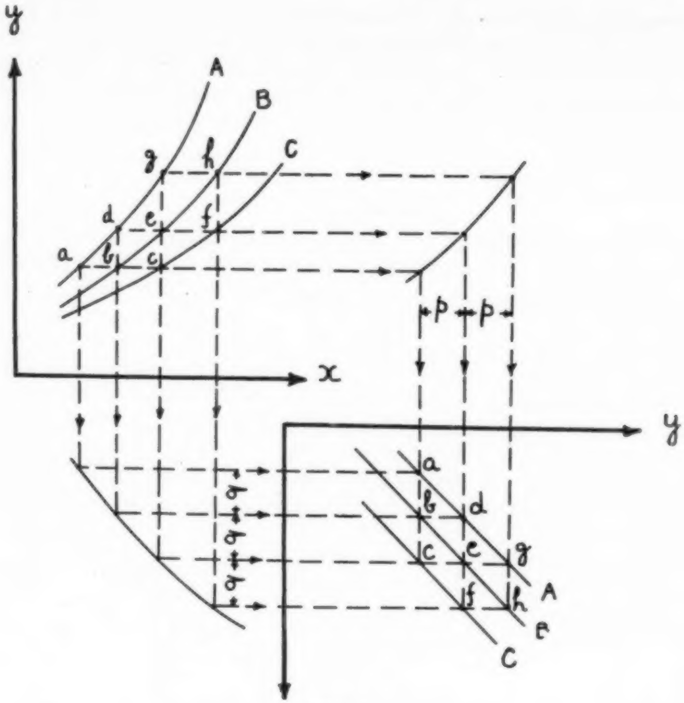
y
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Fig. 3.

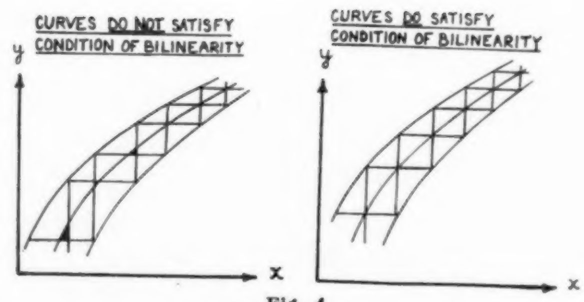

CURVES DO NOT SATISFY CONDITION OF BILINEARITY
y
x
CURVES DO SATISFY CONDITION OF BILINEARITY
y
x

Fig. 4.

or in determinant form as in (A). Therefore if y_a and x_a are functions of a only, then $y = y_a$ and $x = x_a$ are the equations which define the locus of a and enable the scale of a to be drawn. The scales of b and c are obtained in a similar manner. The noteworthy features of determinant E.1 are (1) functions in one row contain

$$\text{(A)} \begin{vmatrix} y_a & x_a & 1 \\ y_b & x_b & 1 \\ y_c & x_c & 1 \end{vmatrix} = 0 \text{ ——— E.1} \qquad \text{(B)} \begin{vmatrix} a & 1 & 0 \\ b & 1 & 1 \\ -c & 0 & 1 \end{vmatrix} = 0 \qquad \text{(C)} \begin{vmatrix} a & 1 & 1 \\ \frac{1}{2}b & \frac{1}{2} & 1 \\ -c & 0 & 1 \end{vmatrix} = 0,$$

only one variable not found in the other two rows, and (2) the elements of one column are unity. This is all the theory needed for simple nomograms. The problem remaining is to convert any formula or equation into the form of determinant E.1.

For example, suppose the equation $a - b = c$ is to be represented by a nomographic chart. First the equation would be written in determinant form as in (B) and then rearranged in the form of E.1 by adding column 2 to column 3 and dividing throughout by the new column 3, giving (C).

By analogy with E.1 it now follows that $y_a = a$; $x_a = 1$; $y_b = \frac{1}{2}b$; $x_b = \frac{1}{2}$; $y_c = -c$; and $x_c = 0$. If the units of measurement are to be inches, scales a and b are seen to be $\frac{1}{2}$ in. apart, and a and c 1 in. apart. Since the multiplication

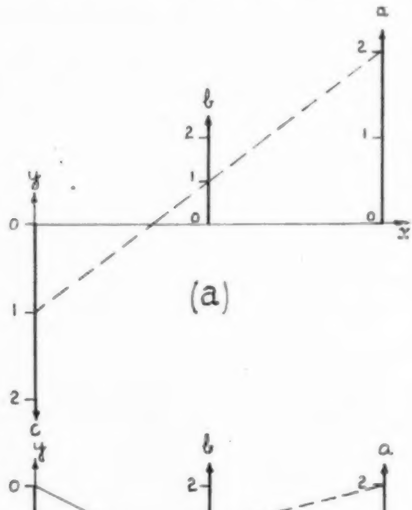


Fig. 5.

of any row or column of a zero determinant by a constant does not affect its value, column 2 can be multiplied by 4 to make scales a and b 2 in. apart. The scales of magnitudes a, b, and c can also be modified by means of this device. In *Fig.* 5a the nomogram is drawn with rectangular axes; an improvement in the accuracy and compactness of the chart is made in *Fig.* 5b simply by plotting the values of x along an oblique axis.

Example.

As a result of analysing experimental and published data it was found that the relation between the strength of 6-in. concrete cubes in lb. per square inch (s), the age of the concrete in days (D), and the water-cement ratio by weight (R), is given approximately by

$$f(s) - a = \frac{1}{b}\left[\frac{D}{D+1} - c\right][R + d]$$

in which a, b, c, and d are arbitrary constants depending only on the type of cement, and $f(s) = \log_{10} \frac{s}{100}$. In determinant form this equation becomes (D).

$$\text{(D)} \begin{vmatrix} -(R+d) & 1 & 1 \\ 0 & \frac{1}{b}\cdot\frac{D}{D+1} - c & -1 \\ f(s) - a & 0 & 1 \end{vmatrix} = 0. \qquad \text{(E)} \begin{vmatrix} (R+d) & 1 & 1 \\ 0 & \dfrac{\frac{D}{D+1} - c}{\frac{D}{D+1} - c - b}\ (=A) & 1 \\ f(s) - a & 0 & 1 \end{vmatrix} = 0,$$

$$\text{(F)} \begin{vmatrix} 11.43(R + 0.17999) & 20A & 1 \\ 0 & 20A & 1 \\ 11.43(\log_{10} \frac{s}{100} - 2.4658) & 0 & 1 \end{vmatrix} = 0$$

Adding column 2 to column 3, and then dividing throughout by column 3, we obtain (E) which is in the form of determinant E.1. The constants for the equation are as follows.

Ordinary Portland cement: $a = 2{\cdot}465800$, $b = 0{\cdot}352859$, $c = 1{\cdot}349503$, $d = 0{\cdot}17999$.

Rapid-hardening Portland cement: $a = 2{\cdot}465800$, $b = 0{\cdot}611942$, $c = 1{\cdot}585518$, $d = 0{\cdot}17999$.

Constants a and d are common to both types of cement, so that only one set of scales for the water-cement ratio R and strength s need be drawn. The constants for the age-scales D differ: these scales must therefore be divided differently for each type of cement, but since the value of y is common to both the same straight line represents both scales.

The determinant used for plotting the nomogram is as in (F). To facilitate the plotting of the s-scale on the nomogram shown in *Fig.* 6 logarithmic graph paper with a log-cycle of 11·43 cm. was used, and column 1 is multiplied by the factor 11·43 so that the scales should correspond. Column 2 is multiplied by 20 to ensure that the scale of D has a reasonable length, and the values are plotted on an oblique axis to reduce the overall size of the chart and improve its accuracy.

Complex Nomograms.

When dealing with equations with more than three variables it is necessary to use two or more determinants linked together by reference lines. As an example, consider the equation $ab - cd = 0$. In determinant form it becomes (G), which cannot be put into the form of E.1. If, however, cd is represented

$$\text{(G)} \begin{vmatrix} a & d & 0 \\ 0 & b & 1 \\ c & 0 & 1 \end{vmatrix} = 0, \quad \text{(H)} \begin{vmatrix} a & 1 & 0 \\ 0 & b & 1 \\ p & 0 & 1 \end{vmatrix} = 0 \text{ and } \begin{vmatrix} p & 0 & 1 \\ c & 1 & 0 \\ 0 & d & 1 \end{vmatrix} = 0,$$

by p, then $ab + p = 0$, which in determinant form becomes (H), both of which can be rearranged in the form of E.1. It is important when rearranging the determinants to make the row containing the reference variable the same in both, to ensure that the reference line has the correct position relative to the other two scales and the same magnitude of scale in both determinants. Most equations with four or five variables can be represented fairly easily in this way, after some experience, but when there are more than five variables the method outlined in the following is quicker.

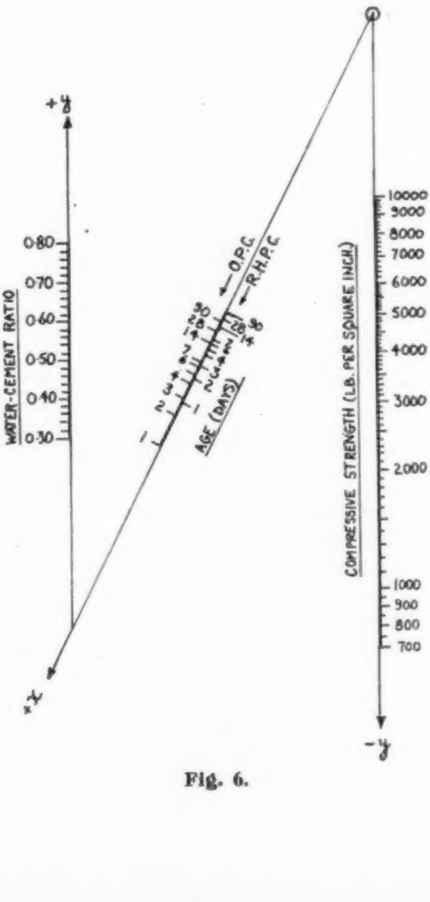


Fig. 6.

The procedure is to split the original equation by means of reference variables into a number of other equations, each of which contains not more than three variables. Each of these is then operated on by a non-zero matrix, the constants of which are solved to meet the scale requirements. The matrix normally used for this purpose is as in (I), which, when used as operator on a determinant such as (J), yields (K), or in the form of E.1 it yields (L).

$$\text{(I)}\begin{vmatrix} 1 & 0 & 0 \\ a_2 & b_2 & c_2 \\ a_3 & 0 & c_3 \end{vmatrix} \neq 0 \qquad \text{(J)}\begin{vmatrix} y_1 & x_1 & z_1 \\ y_2 & x_2 & z_2 \\ y_3 & x_3 & z_3 \end{vmatrix} = 0$$

$$\text{(K)}\begin{vmatrix} y_1 + x_1a_2 + z_1a_3 & x_1b_2 & x_1c_2 + z_1c_3 \\ y_2 + x_2a_2 + z_2a_3 & x_2b_2 & x_2c_2 + z_2c_3 \\ y_3 + x_3a_2 + z_3a_3 & x_3b_2 & x_3c_2 + z_3c_3 \end{vmatrix} = 0 \qquad \text{(L)}\begin{vmatrix} \dfrac{y_1 + x_1a_2 + z_1a_3}{x_1c_2 + z_1c_3} & \dfrac{x_1b_2}{x_1c_2 + z_1c_3} & 1 \\ \dfrac{y_2 + x_2a_2 + z_2a_3}{x_2c_2 + z_2c_3} & \dfrac{x_2b_2}{x_2c_2 + z_2c_3} & 1 \\ \dfrac{y_3 + x_3a_2 + z_3a_3}{x_3c_2 + z_3c_3} & \dfrac{x_3b_2}{x_3c_2 + z_3c_3} & 1 \end{vmatrix} = 0$$

The conditions used to determine the constants a, b, and c are normally (1) width of diagram, (2) length of scale of two variables, and (3) limiting values of two variables. To illustrate the method, consider the equations used for estimating quantities of concrete:

$$W = \frac{1685}{0{\cdot}317 + \dfrac{P}{r} + R}, \text{ and } V = \frac{c\left(0{\cdot}317 + \dfrac{P}{r} + R\right)}{62{\cdot}4},$$

in which W is the weight of cement (lb. per cubic yard of finished concrete), P the aggregate-cement ratio (by weight), r the specific gravity of the aggregate, R the water-cement ratio (by weight), V the volume of concrete (cu. ft. per batch), and c the weight of cement per batch. To produce equations containing not more than three variables, the following substitutions are necessary:

$$u = (0{\cdot}317 + R) + w, \text{ in which } w = \frac{P}{r}.$$

Hence $W = \dfrac{1685}{u}(1)$; $u = (0{\cdot}317 + R) + w(2)$; $w = \dfrac{P}{r}(3)$; $V = \dfrac{cu}{62{\cdot}4}(4)$.

These are the equations to be put into the form of E.1 by means of a matrix. Equation (1) is the simplest since it contains only two variables and will therefore be considered first. The remaining equations are considered in the same way.

Equation (1): $\dfrac{1685}{W} - u = 0$. This is shown in determinant form in (M), which on rearranging becomes (N).

Operation with the non-zero matrix (I) gives (O), which in nomographic form becomes (P).

Solution of Constants.—(i) Make u-scale such that when $u = 1$, $y = 1$; and when $u = 6$, $y = 5$. Then $1 + a_2 + a_3 = c_2 + c_3$ and $6 + a_2 + a_3 = 5c_2 + 5c_3$. Hence $a_2 + a_3 = \frac{1}{4}$ (a) and $c_2 + c_3 = \frac{5}{4}$ (b).

(ii) Let 1000 on W-scale be at $y = 7$, and 300 on W-scale be at $y = 2$.

Then $\dfrac{(1 - a_2)1000 + 1685a_3}{1685c_2 - 1000c_2} = 7$ (c), and $\dfrac{(1 - a_2)300 + 1685a_3}{1685c_3 - 300c_2} = 2$ (d).

Solving equations (a), (b), (c), and (d), $a_2 = -0{\cdot}479$, $a_3 = 0{\cdot}729$, $c_2 = 0{\cdot}640$, and $c_3 = 0{\cdot}610$, and the determinant now becomes as in (Q) or (R).

(iii) Let the distance between the u-scale and the farthest point on the W-scale (at $W = 1000$) be 10 in.

Then
$$0{\cdot}80b_2 + \frac{1000b_2}{1028 - 640} = 10, \text{ and } b_2 = 2{\cdot}96.$$

The final form of the determinant is as in (S).

In *Table* 1 are shown some of the co-ordinates used for setting out the chart, and *Fig.* 8 shows the relative positions of the scales.

The determinants for equations (2), (3), and (4) are found by the processes outlined for equation (1), and the complete nomogram is shown in *Fig.* 7. The solution of each equation in turn establishes the position of other axes, which are superimposed on those previously established. For example, the relative positions of the axes for y and R are found from equation (2).

The graphical constructions described in the foregoing have been found useful for the representation of empirical data. The analytical methods should not be difficult to those well versed in algebra, but the beginner is advised not to attempt the matrix method before drawing a nomogram by one of the simpler methods. The pitfalls are few, but real, and it is only with experience that they can be avoided.

$$(\mathrm{M})\begin{vmatrix} 1 & 1 & 0 \\ 0 & u & 1 \\ \frac{1685}{W} & 0 & -1 \end{vmatrix} = 0 \qquad (\mathrm{N})\begin{vmatrix} 1 & 0 & 1 \\ u & 1 & 1 \\ \frac{W}{1685} & \frac{-W}{1685} & 1 \end{vmatrix} = 0$$

$$(\mathrm{O})\begin{vmatrix} 1 + a_3 & 0 & c_3 \\ u + a_2 + a_3 & b_2 & c_2 + c_3 \\ \frac{W}{1685} - \frac{a_2W}{1685} + a_3 & \frac{-b_2W}{1685} & \frac{-Wc_2}{1685} + c_3 \end{vmatrix} = 0 \qquad (\mathrm{P})\begin{vmatrix} \frac{1 + a_3}{c_3} & 0 & 1 \\ \frac{u + a_2 + a_3}{c_2 + c_3} & \frac{b_2}{c_2 + c_3} & 1 \\ \frac{W - a_2W + 1685a_3}{1685c_3 - c_2W} & \frac{-b_2W}{1685c_3 - Wc_2} & 1 \end{vmatrix} = 0$$

$$(\mathrm{Q})\begin{vmatrix} \frac{1 + 0.729}{0.610} & 0 & 1 \\ \frac{u - 0.479 + 0.729}{0.640 + 0.610} & \frac{b_2}{0.640 + 0.610} & 1 \\ \frac{1.479W + 1685 \times 0.729}{1685 \times 0.610 - 0.640W} & \frac{-b_2W}{1685 \times 0.610 - 0.640W} & 1 \end{vmatrix} = 0 \qquad (\mathrm{R})\begin{vmatrix} 2.84 & 0 & 1 \\ 0.80u + 0.20 & 0.80b_2 & 1 \\ \frac{1.479W + 1229}{1028 - 0.64W} & \frac{-b_2W}{1028 - 0.64W} & 1 \end{vmatrix} = 0$$

$$(\mathrm{S})\begin{vmatrix} 2.84 & 0 & 1 \\ 0.80u + 0.20 & 2.368 & 1 \\ \frac{1.479W + 1229}{1028 - 0.64W} & \frac{-2.96W}{1028 - 0.64W} & 1 \end{vmatrix} = 0$$

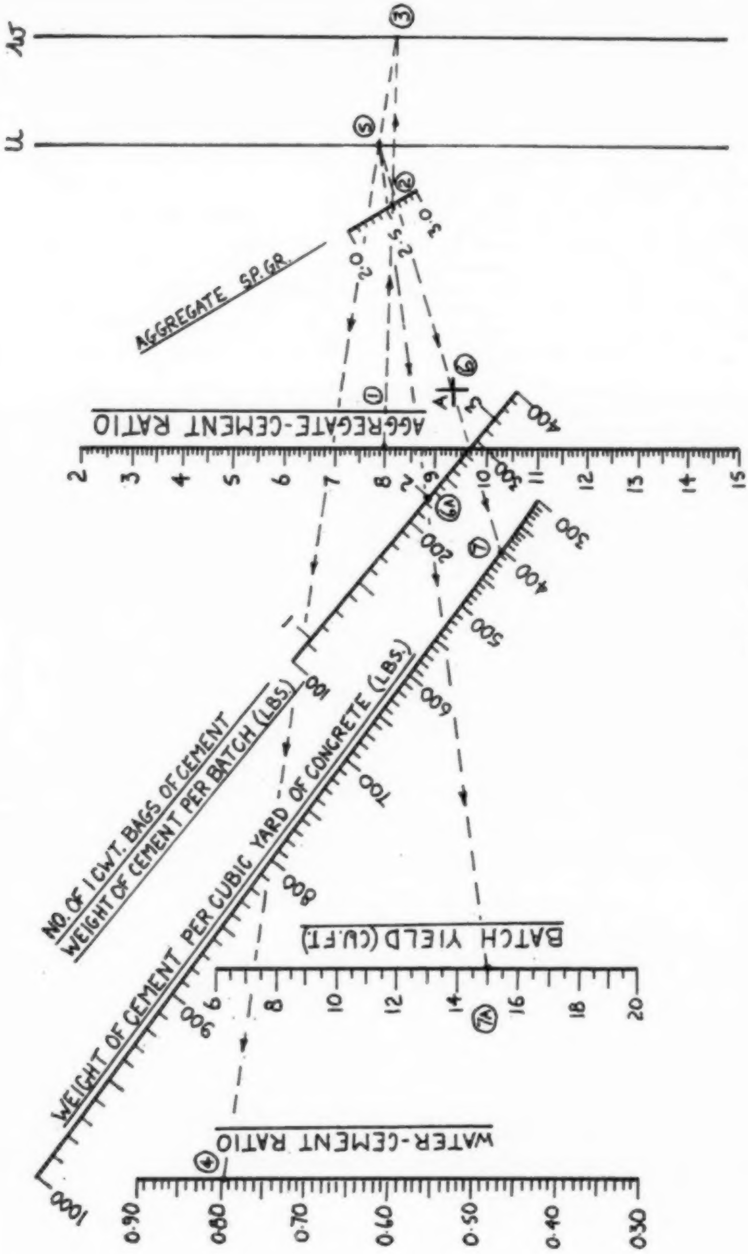

AGGREGATE SP.GR.
AGGREGATE-CEMENT RATIO
NO. OF 1 CWT. BAGS OF CEMENT
WEIGHT OF CEMENT PER BATCH (LBS.)
WEIGHT OF CEMENT PER CUBIC YARD OF CONCRETE (LBS.)
BATCH YIELD (CU.FT.)
WATER-CEMENT RATIO

Fig. 7.

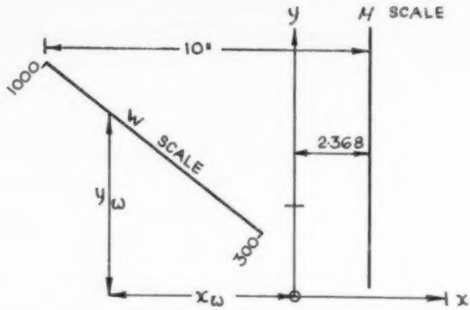


Fig. 8.

TABLE I.

W	300	400	500	600	700	800	900	1000
-X	1.06	1.33	2.09	2.76	3.57	4.58	5.88	7.64
y	2.00	2.36	2.78	3.28	3.91	4.65	5.65	7.00

ACKNOWLEDGMENT.—Part of the foregoing work was carried out during the course of the writer's duties and is published with the permission of Messrs. George Wimpey & Co., Ltd.

A Structural Laboratory in U.S.A.

A NEW laboratory for the Portland Cement Association of America has a test-floor 120 ft. by 56 ft. for testing beams, slabs, and other structural members. A slab the size of the entire floor can be tested to destruction, and slabs can be subjected to loads up to 30,000 lb. per square foot. The floor is of cellular construction 12 ft. deep and comprises a top slab 2 ft. thick, a bottom slab 18 in. thick, and five longitudinal vertical webs. The top slab is perforated with holes of 2½-in. diameter at 3 ft. centres in two directions. A force of 100,000 lb. acting vertically in either direction can be resisted at each hole and the capacity of the entire floor is about 4460 tons.

The laboratory is equipped with hydraulic jacks capable of exerting a total force of about 1800 tons. Four Swiss hydraulic jacks, each capable of applying a load of 22,000 lb. at the rate of 250 or 500 times each minute are available for cyclic load tests. The loads on jacks are measured by oil-pressure gauges. Moments, applied forces, and shearing forces are measured by electronic devices designed and made by the staff of the laboratory. Strains are measured by mechanical and electrical strain-gauges and are recorded by hand-operated strain-indicators or by automatic recorders. Deflections are measured by gauges or by levelling, which are accurate to 0·002 in. Movements at a distance from any fixed point are measured by triangulation which is accurate to 0·01 in. Horizontal forces are resisted by the frictional forces developed by fastening concrete buttresses to the floor with highly-stressed bolts; a coefficient of friction of 0·5 is generally sufficient for this purpose, but a coefficient of almost unity can be developed by this unusual method.

New Railway Works at Ilford.

CARRIAGE SHED, WATER TOWER, AND CHIMNEY.

A CARRIAGE shed, a boiler house, and a water-tower to supply water for washing carriages in the shed have been erected at Ilford for the Eastern Region of British Railways.

Carriage Shed.

The shed (*Fig.* 1) is 653 ft. long and 256 ft. wide and has a roof of aluminium carried on castellated steel purlins which are supported on prestressed concrete beams extending transversely over four bays. The end spans are 66 ft. wide and the intermediate spans 61 ft. wide. The columns supporting the beams are also of prestressed concrete, double columns being provided at each of the two expansion joints across the shed. Trestles of precast columns braced by horizontal reinforced concrete beams cast in place act as buttresses at the ends of the shed to resist the pull exerted by the overhead electric conductor wires. The floor comprises platforms of prestressed slabs between the rail tracks. The foundations are on clay.

The roof beams are carried on corbels on the columns (*Fig.* 2) and are designed to be freely supported. They are retained by two $\frac{3}{4}$-in. bolts passing through vertical flanges on the ends of each beam and through the top of the column. The bolts are provided with spring-washers to allow small movements at the ends of the beams. On the soffit of each beam, at the seating, there is a $1\frac{1}{4}$-in. steel plate which bears on a pair of plates fixed to the corbel on the column (*Fig.* 3). A gasket of reinforced plastic is inserted between the plate on the beam and the upper plate on the column. Sheet lead $\frac{1}{8}$ in. thick is provided between the lower plate and the concrete corbel. The top of the corbel was ground to a smooth surface and the lugs on the underside of the lower plate embedded in lead in pockets in the corbel. A high-tensile steel pin fixed in the upper plate projects into the plate on the beam. After the beam was placed in position, the two plates on the column were welded together by medium-heat tack-welding so that the joint is capable of transmitting the horizontal wind forces to all the columns.

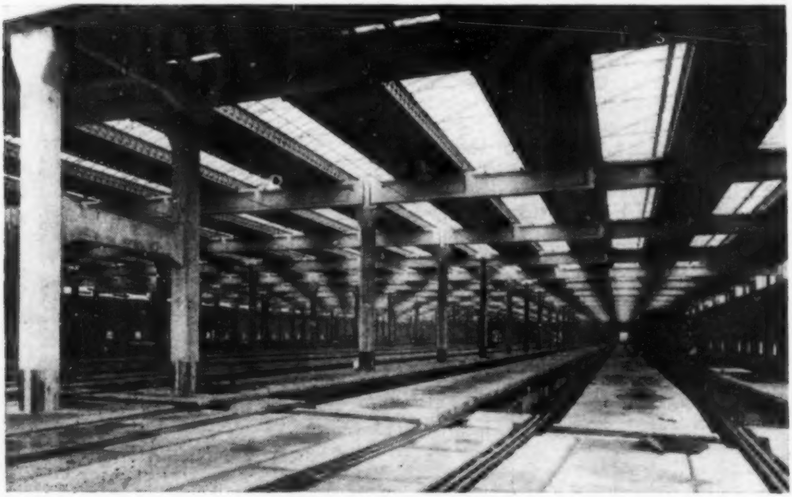


Fig. 1.—Carriage Shed.

The beams are prestressed with pre-tensioned wires and are identical, except that the beams for the end spans also contain a curved post-tensioned cable and

the web is thicker at the end of each beam to provide space for the cable. The same moulds were used for all the beams, but were modified for the thicker web. The calculated tensile stress in the concrete under working load is 750 lb. per square inch. There are 88 beams and all were tested before erection.

The columns are of I-section and it is claimed that their cost is two-thirds that of square reinforced concrete columns. They are prestressed by pre-tensioned wires which produce a compression of 450 lb. per square inch in the concrete. They are also reinforced with twisted ribbed bars to resist bending.

The floor slabs which cover the ducts between the rail-tracks inside the shed were cast in wooden moulds on a prestressing bed at a precasting works (*Fig.* 4). The top faces are slightly dished to drain away water during the washing of carriages. An indented non-slippery surface was produced by pressing small-gauge expanded metal into the top of the slab before the concrete had hardened. A watertight filling is formed in the joint between the slabs by inserting a plug of dry mortar at the bottom of the joint, wet mortar in the rebates in the sides of the slabs, and a bituminous seal at the top.

Water Tower and Chimney.

The water tower (*Fig.* 6) is built around a reinforced concrete chimney connected to the boilerhouse. The chimney, which is about 68 ft. high, was erected first and is on a circular raft separate from the foundation of the water tower. The external diameter is 4 ft., and the wall is

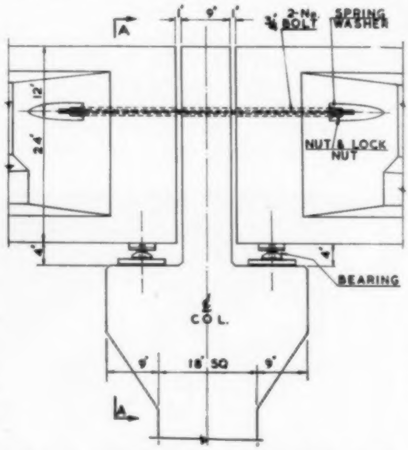


Fig. 2.—Assembly at Top of Columns.

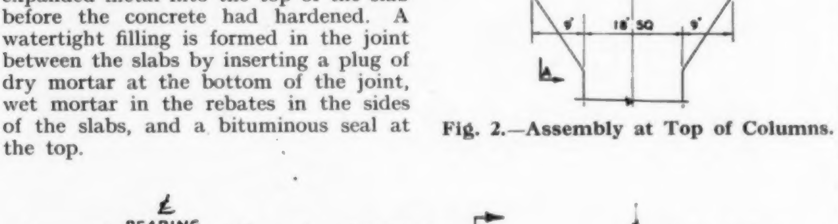


Fig. 3.—Bearings of Beams.

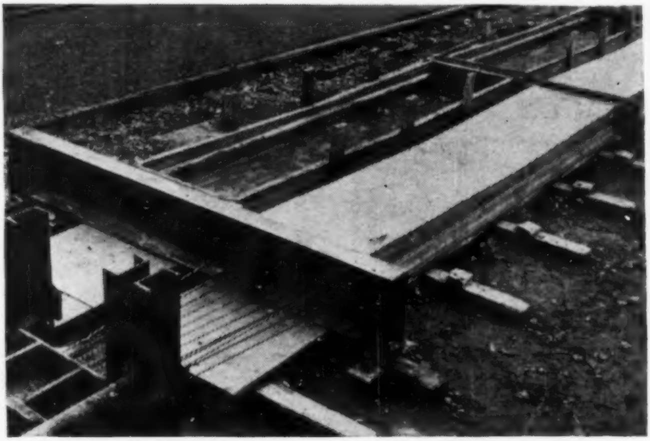


Fig. 4.—Making Prestressed Floor Slabs.

5 in. thick plus a 4½-in. refractory-brick lining. The cap comprises eight precast segments of sulphate-resistant concrete. For a distance of 3 ft. from the top the shaft is 4½ in. thick, and there is an insulating layer ½ in. thick between the concrete and the lining. At the connection of the flue with the shaft, the concrete cast in place is lined with refractory brick on the bottom and sides and a precast lintel (L) and slabs (B), both of refractory concrete, are provided at the top. The expansion gap between the connection to the shaft and the flue is covered by a strip of asbestos cloth 12 in. wide (R). The cavity in the base of the shaft is lined with ordinary brick and filled with consolidated hardcore, the surface of which is covered with a 2-in. layer of lean concrete on which the refractory lining of the shaft is laid.

The water tower is of reinforced concrete. The tank is 28 ft. diameter and about 10 ft. deep and has a capacity of 30,000 gallons. The bottom of the tank is 51 ft. above the ground and is supported on six braced columns. The foundation slab (*Fig.* 5) is annular. The tank is also annular and is entirely separate from the chimney which passes through the centre. To ensure freedom of movement due to the pressure of the water the outer wall is not monolithic with the bottom or the roof, and the inner wall is also separate from the bottom. Details of the joints between the walls, the roof, and bottom are shown in *Fig.* 6. The slab at ground level comprises a 6-in.

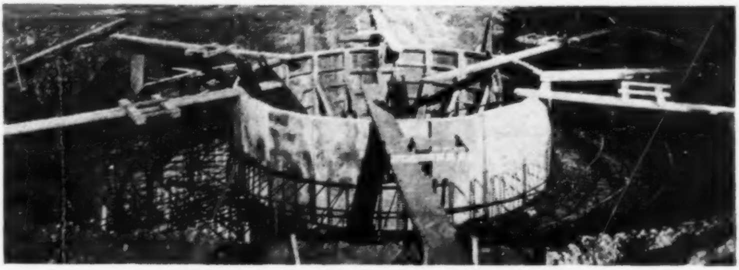


Fig. 5.—Foundation of Water Tower.

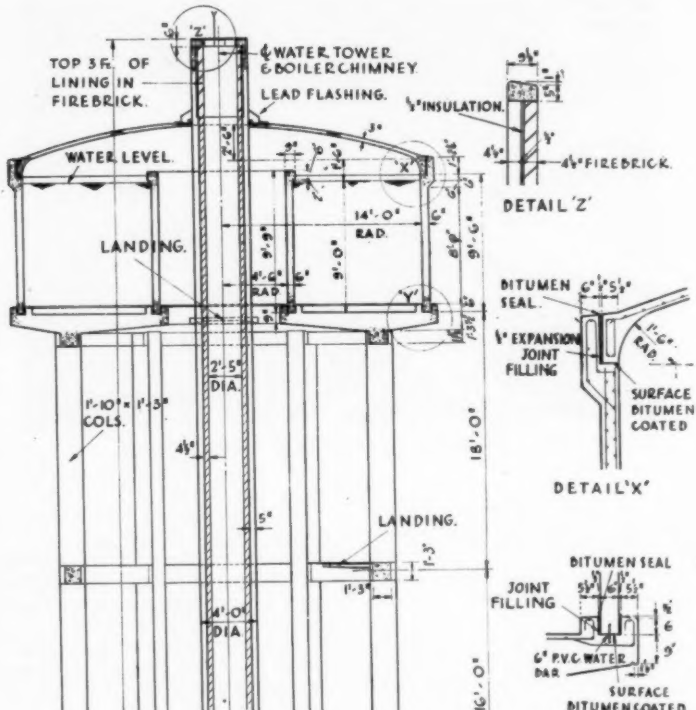


Fig. 6.—Section Through Water Tower and Chimney.

reinforced concrete slab laid on 3 in. of consolidated clinker. For a width of about 4 ft. the slab is paved with cobblestones (C) set in cement.

The design and construction of the works were under the general direction of Mr. A. K. Terris, M.I.C.E., Chief Civil Engineer, Eastern Region of British Railways. The general contractors for the shed and water tower were Messrs. W. & C. French, Ltd., who made the slabs for the floors. The chimney was erected by Messrs. Tileman & Co., Ltd. The columns and beams were precast by Costain Concrete, Ltd.

Reservoir at Middlesbrough.

A SERVICE reservoir of 10,000,000 gall. capacity constructed for Imperial Chemical Industries, Ltd., for their works at Wilton, is shown in *Fig.* 1. It is cut into a hillside with a slope of 1 in 10, and required the excavation of 108,000 cu. yd. of hard clay. The formation was covered with 4 in. of plain concrete upon which an 8-in. reinforced concrete slab was laid over an area of 10,600 sq. yd. The floor, which has a crossfall of 8 in., was constructed in bays of 28 ft. 3 in. by 20 ft. with PVC hydrofoil waterstop placed continuously throughout the intersections of all the slabs and the walls; the joints between the bays were filled with mastic compound. The PVC waterstop was butt-welded on the site to suit the sizes of the bays; the material for the intersections was formed before delivery to the site. The reinforcement comprises two layers of steel fabric and is continuous through all the construction joints, which amount to about 60 per cent. of all the joints in the reservoir.

The sides slope at 1½ to 1 and are lined with a concrete slab 8 in. thick reinforced with two layers of steel fabric. The trimmed sides were coated with a latex emulsion to maintain the moisture content of the clay prior to the concreting of the sides. The depth from the floor to top water level is 15 ft. *Fig.* 2 shows the general arrangement.

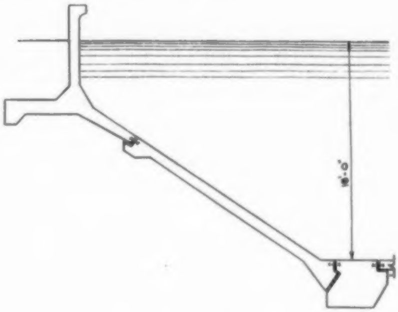


Fig. 2.

The concrete was specified to have a crushing strength of 3500 lb. per square inch at seven days, and a plasticiser was included in the mixture. The work was designed and supervised by the engineering staff of Imperial Chemical Industries, Ltd., and done by Messrs. A. Monk & Co., Ltd.

Fig. 1.

Book Reviews.

"Civil Engineering Contracts and Organization." By J. C. Maxwell-Cook. (London : Cleaver-Hume Press, Ltd. 1959. Price 22*s*. 6*d*.)

THIS book, which is written for young resident engineers and contractors' agents, provides a good descriptive guide to contractual procedure in connection with civil engineering. The author is at his best when dealing with matters concerning the contractors' operations and organization. In other matters some details are questionable ; for example, the contract drawings need not give information regarding the nearest sand and ballast pits and local labour exchange ; nor is the quantity surveyor responsible for the specification, which must be the engineer's responsibility. Typical specifications are given for excavation, concrete, prestressed concrete, brickwork and masonry, steelwork, piling, waterproofing, sewers and drains, roads, railways, and timber construction, but these should not be accepted as models as many of the poorer features of common specifications are reproduced. The short specification for concrete is weak. The descriptions of the requirements range from extreme looseness to such rigid stipulations as "the concrete shall be watertight" and shall be cut out if it does not pass the tests required by the engineer ; unless such tests, and many other requirements, are described in the specification it is unreasonable to expect "truly competitive tenders to be obtained" and to avoid disputes regarding the interpretation of the specification as the work proceeds.

"Mechanical Properties of Non-metallic Brittle Materials." (London : Butterworth's Scientific Publications. Price £4 10*s*.)

A CONFERENCE on non-metallic brittle materials, organised by the Mining Research Establishment of the National Coal Board, was held in London in April 1958, and the proceedings are published in this volume of 492 pages. The subjects discussed were (1) strength in compression, bending, and shear, (2) elasticity and creep, (3) dynamic loading, impact, and fragmentation, and (4) the action of tools. The materials dealt with include coal, concrete, gypsum, bricks, glass, rocks, ceramics, carbon and graphite, and stone. The papers on tools relate to the effect of the angle of blades, friction, the force required for penetration, and the cutting and ploughing of coal. The papers on concrete deal with the failure of test specimens in compression and bending ; elasticity, creep, and shrinkage ; the effect of the rate of loading ; the strength of beams under dynamic loading ; and the penetration of roller bits.

"Plastic Design of Steel Frames." By Lynn S. Beedle. (London : Chapman & Hall, Ltd. Price £5 4*s*.)

THIS is claimed to be the first book published in the U.S.A. which deals solely with the subject. The first six chapters deal with the theory and methods of analysis, and the remainder of the 400 pages describe design procedure including examples. The author states that the application of the ultimate-load method of design to steel structures was first propounded by Dr. Kazinczy in Hungary in the year 1914. The results of the investigations of Professor J. F. Baker at Cambridge University were published in 1949, and the application of the method to concrete structures is described by Professor A. L. L. Baker, of Imperial College, London, in his book "Ultimate Load Theory Applied to Design of Reinforced and Prestressed Concrete Frames" published in 1956.

"The Frost Resistance of Cement Paste as Influenced by Surface-active Agents." By Ulf Danielsson and Anders Wastesson. (Stockholm : Swedish Cement & Concrete Research Association. No price stated.)

A REPORT on an investigation of the effect on the resistance to frost of concrete containing surface-active chemicals used for improving workability and watertightness. The view is expressed that the difference in the sizes of the pores in concrete is important, and a formula is given for estimating the resistance of concrete to frost taking into account the air content of the cement paste, the specific surface area of the pores, the water cement ratio, the age of the paste, the conditions to which the concrete will be subjected, and other factors.

Design of Slabs for Rectangular Tanks.

By G. P. MANNING, M.Eng., M.I.C.E.

THE accompanying charts facilitate the design of the walls and bottoms of rectangular containers of liquids and can be used when the bending moment causes tension in the face in contact with the liquid. The requirements and stresses are in accordance with the proposals for a British Standard Code for such structures. There are two conditions for design.

(1) For 1 : 1·6 : 3·2 concrete a compressive stress of 1200 lb. per square inch in the concrete and a tensile stress of 12,000 lb. per square inch in the reinforcement should not be exceeded. The tensile strength of the concrete is neglected in this calculation. The modular ratio m is assumed to be 15. The curves marked " strength " in *Figs.* 1, 2, and 3 show the bending strengths of rectangular members reinforced in tension only or in tension and compression for three positions of the reinforcement. *Fig.* 1 usually applies to slabs about 5 in. thick, *Fig.* 2 to slabs about 9 in. thick, and *Fig.* 3 to slabs about 20 in. thick.

(2) Assuming that the concrete is uncracked and that m is 15, the tensile stress in the concrete should not exceed the safe tensile stress p_{ct} in bending. This provision is intended to ensure the absence of cracks. The bending strengths of rectangular members with p_{ct} = 300 lb. per square inch are shown by the curves marked " crack " in *Figs.* 1, 2, and 3. If any other safe tensile stress

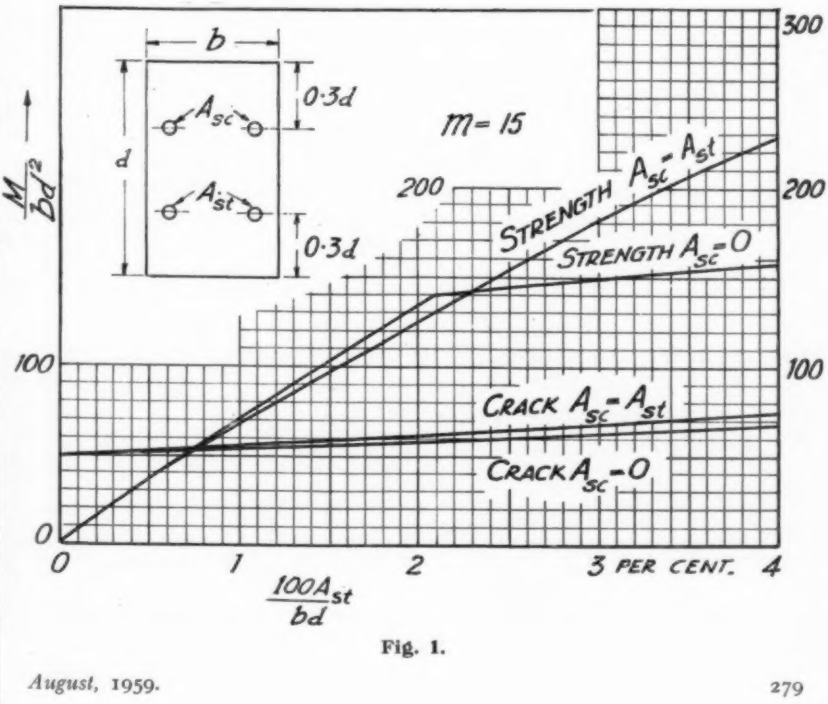


Fig. 1.

is specified the moment-of-resistance factor for any given percentage of reinforcement is obtained by multiplying the factor on the diagrams by $\frac{p_{ct}}{300}$. Recommended values of p_{ct} are 270 lb. per square inch in 1 : 1·6 : 3·2 concrete and 245 lb. per square inch in 1 : 2 : 4 concrete. Except when the percentage of reinforcement is very small, these curves are much below those marked "strength".

For a rectangular section with reinforcement in tension only, with working stresses of 1200 lb. per square inch in the concrete and 12,000 lb. per square inch in the reinforcement, and $m = 15$, $\frac{M}{bd_1^2} = 288$, and the reinforcement required is 3 per cent. of the area bd_1. Because the second recommendation is based on the overall depth d whereas the first is based on the effective depth d_1, the ratio $\frac{d_1}{d}$ is important. The bending strengths in *Figs.* 1, 2, and 3 are therefore shown in terms of bd^2 and the percentage of reinforcement in terms of bd. In *Fig.* 3, for example, $d_1 = 0{\cdot}9d$, and if the area of the tensile reinforcement is 3 per cent. of bd_1 (that is 2·7 per cent. of bd) and $A_{sc} = 0$, then $\frac{M}{bd^2} = 233$ corresponds to $\frac{M}{bd_1^2} = 288$. For the same section the value of $\frac{M}{bd^2}$ given by the

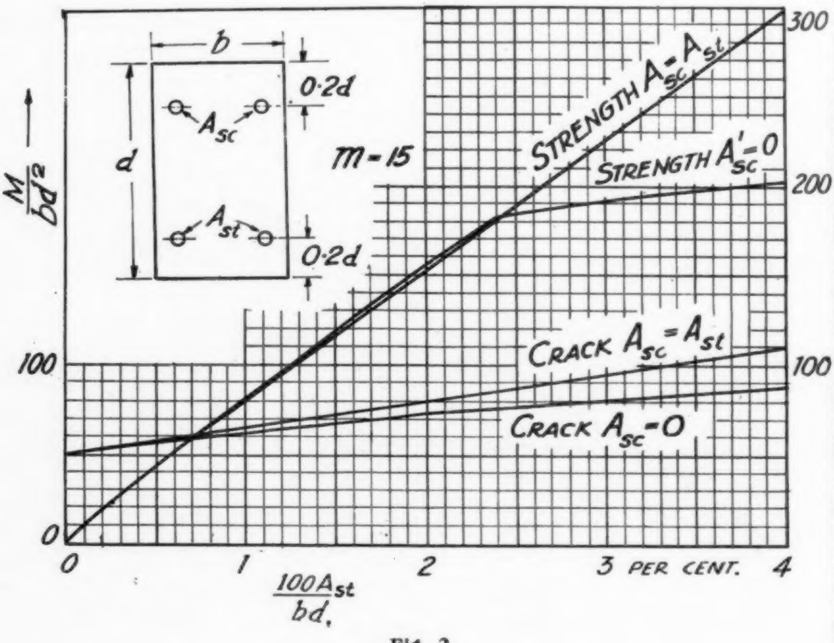


Fig. 2.

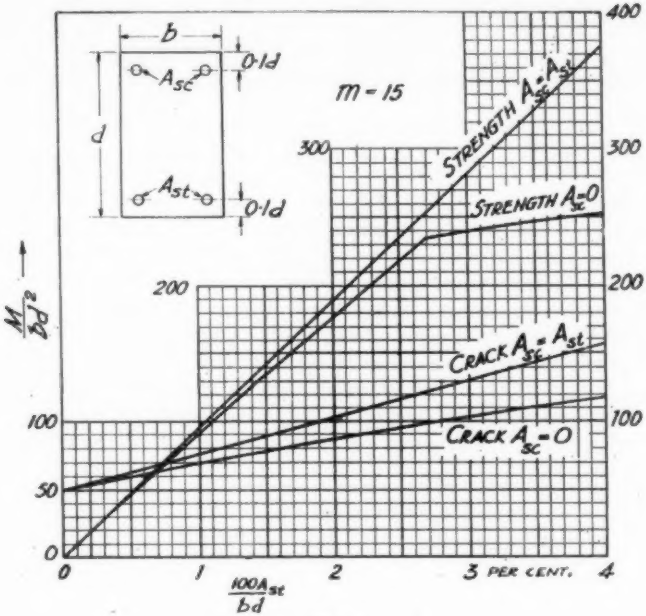


Fig. 3.

curve marked "crack" is about 100, which is only about 42 per cent. of that given by the curve marked "strength". It follows, therefore, that design for "no cracking" determines the thickness of the slab, and design for "bending strength" determines the amount of reinforcement.

The walls of reservoirs may be subjected to a resultant pressure on either face, depending on whether the reservoir is empty or full, and reinforcement must therefore be provided in both faces. If $d_1 = 0{\cdot}9d$ and $A_{sc} = A_{st}$ the curves in *Fig.* 3 marked "strength" and "crack" intersect at about $\frac{M}{bd^2} = 70$, and the area of reinforcement is 0·75 per cent. of bd at each side.

The foregoing considerations apply to unlined reservoirs. If a reliable plastic lining be used which is capable of stretching and bridging over a crack about 0·001 in. wide, stresses of 1200 lb. per square inch in the concrete and 18,000 lb. per square inch in the reinforcement to resist tension could be adopted, without reference to the tensile stress in the concrete.

EXAMPLE.—A dividing wall in a reservoir is to be designed as a cantilevered slab to resist a head of 15 ft. of water acting on either side.

$$M = \frac{1}{6} \times 62{\cdot}5 \times 15^3 = 35{,}200 \text{ ft.-lb.} = 422{,}000 \text{ in.-lb. per foot of wall.}$$

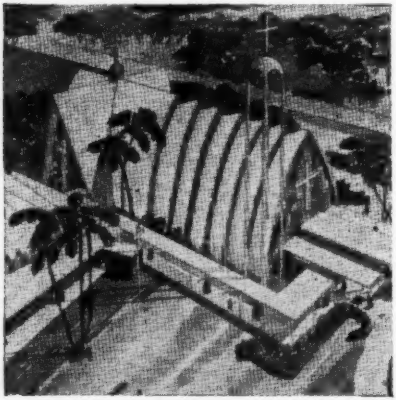
Assume $\frac{d_1}{d}$ to be 0·9. The curves marked "strength $A_{sc} = A_{st}$" and "crack

$A_{sc} = A_{st}$ " in *Fig.* 3 intersect at $\frac{M}{bd^2} = 70$, and the percentage of reinforcement is 0·75. The least permissible overall depth d is $\sqrt{\frac{422{,}000}{70 \times 12}} = 22{\cdot}4$ in., say, $22\frac{1}{2}$ in. $A_{sc} = A_{st} = 0{\cdot}75$ per cent. of $12 \times 22{\cdot}4 = 2{\cdot}02$ sq. in. Provide 1-in. bars at $4\frac{1}{2}$-in. centres. If the cover is $1\frac{1}{2}$ in., $d_1 = 20\frac{1}{2}$ in. $= 0{\cdot}91d$; if the cover is 2 in., $d_1 = 20$ in. $= 0{\cdot}89d$. Both values are sufficiently close to the assumed value of $0{\cdot}9d$.

The observance of the " no-cracking " rule leads to a much thicker wall than is required for strength alone, but this does not mean that such a design is uneconomical. In the example given, with stresses of 1200 lb. per square inch in the concrete and 12,000 lb. per square inch in the reinforcement, sufficient strength could be obtained with a wall 13 in. thick reinforced with 1-in. bars at $2\frac{3}{8}$-in. centres at each face. Assuming that the wall tapers uniformly to a thickness of 7 in. at the top, the average thickness would be reduced from $14\frac{3}{4}$ in. to 10 in., with a saving of 32 per cent. of the concrete (0·22 cu. yd. per foot of wall) but an increase of nearly 100 per cent. of the main reinforcement (1·1 cwt. per foot of wall).

Polystyrene as Shuttering.

THE curved walls and roof of a church in Houston, Texas, U.S.A., will be formed of a layer of foamed polystyrene on to



which concrete will be sprayed to a thickness of $1\frac{1}{2}$ in. The plastic will serve as insulation when the structure is complete ; it is stated to be pliable and easily formed to the required shape.

Concrete Demolished by Powder Lances.

THE demolition of a turbine-testing pit at Schenectady, New York, U.S.A., by means of powder lances has recently been completed. The lance comprises a handle to which are attached one or more pieces of iron pipe. Powdered iron, powdered aluminium, and oxygen, are supplied to the lance; the materials are mixed in the handle, and when ignited produce a high-velocity flame at the end of the pipe. The powdered iron is rapidly oxidised in the flame, thereby greatly increasing its temperature and cutting action.

The pit was hexagonal in plan and consisted of two concentric walls, the outer being 4 ft. thick and the inner 3 ft. thick. The walls were 6 ft. apart, the space between them being packed with sand. Cuts were formed at the rate of 18 in. per hour, the concrete being divided into sections measuring 20 ft. by 16 ft. and weighing 18 tons; the sections were removed by means of a crane. It is stated that a considerable saving of time and cost was achieved by the use of the method. Cuts have been made in this way in concrete with a thickness of 12 ft.

Design of Helical Staircases—3.*

Statically-Indeterminate Cases.

By JACQUES S. COHEN.

Example.

Consider the staircase shown in *Fig.* 6, in which $a = 2$ ft. 11 in., $a_1 = 1$ ft. 9 in., $a_2 = 5$ ft. 3 in., $\delta = \dfrac{4\pi}{3} = 240$ deg. $= 4{\cdot}18879$ radians, and the height is 11 ft. 3 in.; timber treads 3 ft. 6 in. long and 2 in. thick are fixed to a helical reinforced concrete beam 1 ft. $1\frac{1}{2}$ in. wide and $8\frac{1}{2}$ in. deep. From equation (13),

$$c = \frac{h}{\delta} = \frac{3 \times 11{\cdot}25}{4\pi} = 2{\cdot}687\,;\quad \cot\phi = \frac{c}{a} = \frac{2{\cdot}687}{2{\cdot}918} = 0{\cdot}922\,;\quad \phi = 47^\circ\ 20'\,;$$

$$\sin\phi = 0{\cdot}735\,;\quad \cos\phi = 0{\cdot}678\,;\quad \tan\phi = 1{\cdot}085.$$

From (14),

$$K = \frac{\sin\phi}{a} = \frac{0{\cdot}735}{2{\cdot}918} = 0{\cdot}252\,;$$

$$s\ \text{(length of helix)} = \frac{\delta}{K} = \frac{4\pi}{3 \times 0{\cdot}252} = 16{\cdot}63\ \text{ft.}\,;$$

$$R\ \text{(position of centroid of each tread)} = \frac{2}{3} \times \frac{5{\cdot}25^3 - 1{\cdot}75^3}{5{\cdot}25^2 - 1{\cdot}75^2} = 3{\cdot}785\ \text{ft.}$$

The weight of the beam is 1915 lb. and the weight of treads and live load (60 lb. per square foot) is 3935 lb., the total being 5850 lb.

Therefore $\quad w = \dfrac{5850}{16{\cdot}63} = 352$ lb. per foot of beam; and

$$m = \frac{3935}{16{\cdot}63} \times (3{\cdot}785 - 2{\cdot}918) = 206\ \text{ft.-lb. per foot of beam.}$$

From equation (35), $\quad \varepsilon = \dfrac{K_1}{K_2} = \dfrac{I_n}{I_b} = \left(\dfrac{8{\cdot}5}{13{\cdot}5}\right)^2 = 0{\cdot}397\,;$

$$\sigma = \frac{I_n}{J}\cdot\frac{E}{G} = \frac{13{\cdot}5 \times 8{\cdot}5^3}{12 \times 0{\cdot}203 \times 13{\cdot}5 \times 8{\cdot}5^3} \times \frac{7}{3} = 0{\cdot}957.$$

From equation (53), $\quad \varepsilon_1 = 0{\cdot}654\,;\ \varepsilon_2 = 4{\cdot}31\,;\ \varepsilon_3 = 1{\cdot}70\,;\ \varepsilon_4 = 0{\cdot}279.$

Inserting these values in equation (56),

$$\begin{array}{l|l} d_1 = 12{\cdot}0. & d_2 = 3{\cdot}0. \\ e_1 = 5{\cdot}96. & e_2 = -\,4{\cdot}75. \\ f_1 = 34{,}425. & f_2 = -\,37{,}910. \end{array}$$

From equations (55) and (57), the values of the six constants are found as follows:

$$C_1 = -\,1983\,;\quad C_2 = -\,394\,;\quad C_3 = -\,682\,;$$
$$C_4 = -\,6277\,;\quad C_5 = -\,821\,;\quad C_6 = +\,7455.$$

Substituting these in (24), the forces and moments are obtained as in (58).

* *Continued from July, 1959.*

$$\left.\begin{aligned}
T_t &= -394\sin\theta - 682\cos\theta + 947\theta - 1983. \\
T_n &= +928\sin\theta - 536\cos\theta. \\
T_b &= +363\sin\theta + 629\cos\theta + 1027\theta - 2152. \\
M_t &= -821\sin\theta + 7455\cos\theta + 1834\theta\sin\theta - 1060\theta\cos\theta + 2997\theta - 6277. \\
M_n &= -7645\sin\theta - 2558\cos\theta + 1442\theta\sin\theta + 2494\theta\cos\theta + 4893. \\
M_b &= +2883\sin\theta - 3191\cos\theta - 1691\theta\sin\theta + 977\theta\cos\theta - 2763\theta + 5788.
\end{aligned}\right\} \quad (58)$$

From equations (58),

$$\begin{aligned}
T_{t0} &= -2665 \text{ lb.}; & T_{t\frac{4\pi}{3}} &= +2665 \text{ lb.}; \\
T_{n0} &= -536 \text{ lb.}; & T_{n\frac{4\pi}{3}} &= -536 \text{ lb.}; \\
T_{b0} &= -1523 \text{ lb.}; & T_{b\frac{4\pi}{3}} &= +1522 \text{ lb.} \\
M_{t0} &= +1178 \text{ ft.-lb.}; & M_{t\frac{4\pi}{3}} &= -1178 \text{ ft.-lb.}; \\
M_{n0} &= +2335 \text{ ft.-lb.}; & M_{n\frac{4\pi}{3}} &= +2335 \text{ ft.-lb.}; \\
M_{b0} &= +2600 \text{ ft.-lb.}; & M_{b\frac{4\pi}{3}} &= -2600 \text{ ft.-lb.}
\end{aligned}$$

These values satisfy equations (31); equations (58) are therefore correct. The maximum and minimum values are obtained by differentiation:

$\dfrac{dT_t}{d\theta} = -394\cos\theta + 682\sin\theta + 947 = 0$: no roots, therefore T_t increases as θ increases.

$\dfrac{dT_n}{d\theta} = +928\cos\theta + 536\sin\theta = 0$ when $\theta = \dfrac{2\pi}{3}$: $T_n\text{max.} = +1072$ lb.

$\dfrac{dT_b}{d\theta} = +363\cos\theta - 629\sin\theta + 1027 = 0$: no roots, therefore T_b increases as θ increases.

$\dfrac{dM_t}{d\theta} = -1881\cos\theta - 5621\sin\theta + 1834\theta\cos\theta + 1060\theta\sin\theta + 2997 = 0$

when $\theta = 0{\cdot}1154\pi$ ($M_t\text{max.} = +1365$ ft.-lb.) and when $\theta = 1{\cdot}2179\pi$ ($M_t\text{min.} = -1365$ ft.-lb.).

$\dfrac{dM_n}{d\theta} = -5151\cos\theta + 4000\sin\theta + 1442\theta\cos\theta - 2494\theta\sin\theta = 0$

when $\theta = 0{\cdot}451\pi$ ($M_n\text{min.} = -494$ ft.-lb.);

when $\theta = \dfrac{2\pi}{3}$ ($M_n\text{max.} = -445$ ft.-lb.); and when $\theta = 0{\cdot}882\pi$ ($M_n\text{min.} = -494$ ft.-lb.).

$\dfrac{dM_b}{d\theta} = +3860\cos\theta + 1500\sin\theta - 1691\theta\cos\theta - 977\theta\sin\theta - 2763 = 0$

when $\theta = 0{\cdot}2023\pi$ ($M_b\text{max.} = +3038$ ft.-lb.) and when $\theta = 1{\cdot}1310\pi$ ($M_b\text{min.} = -3038$ ft.-lb.).

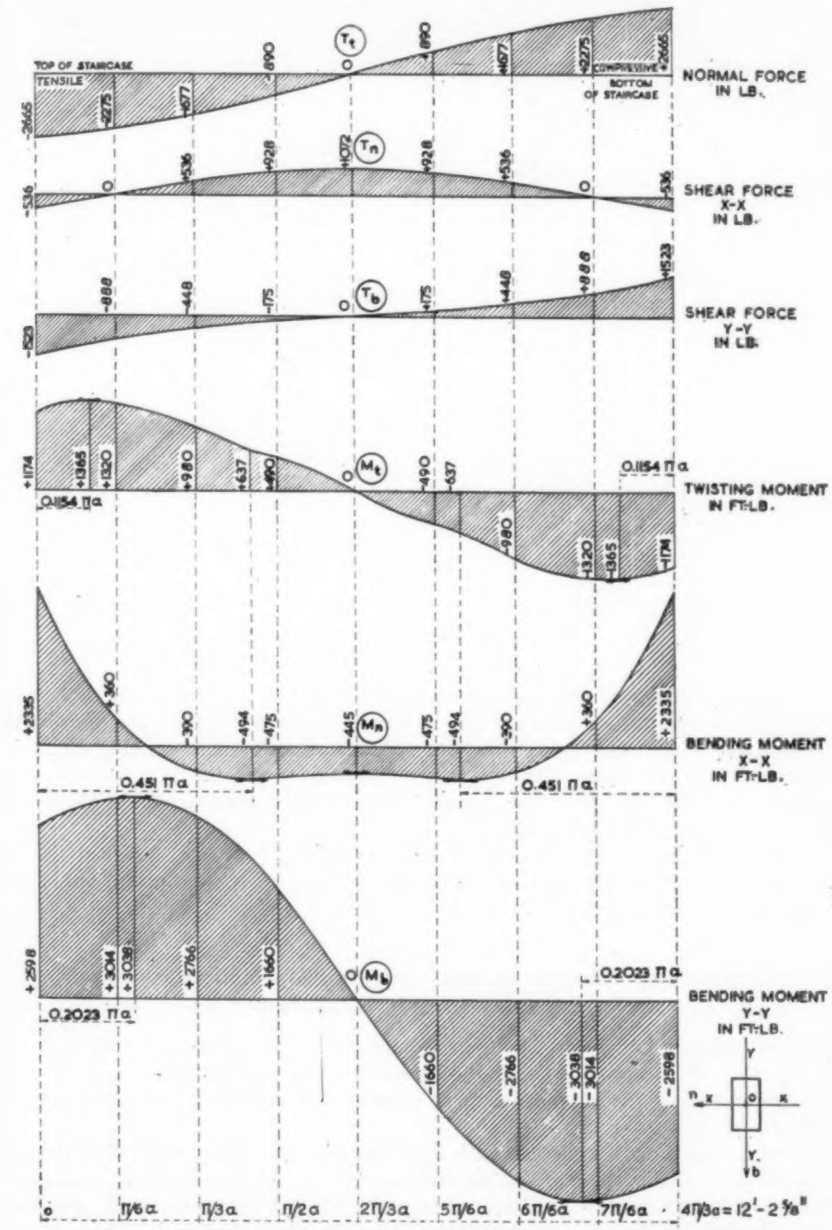


Fig. 13.—Diagram of Forces and Moments with Both Ends Fixed.

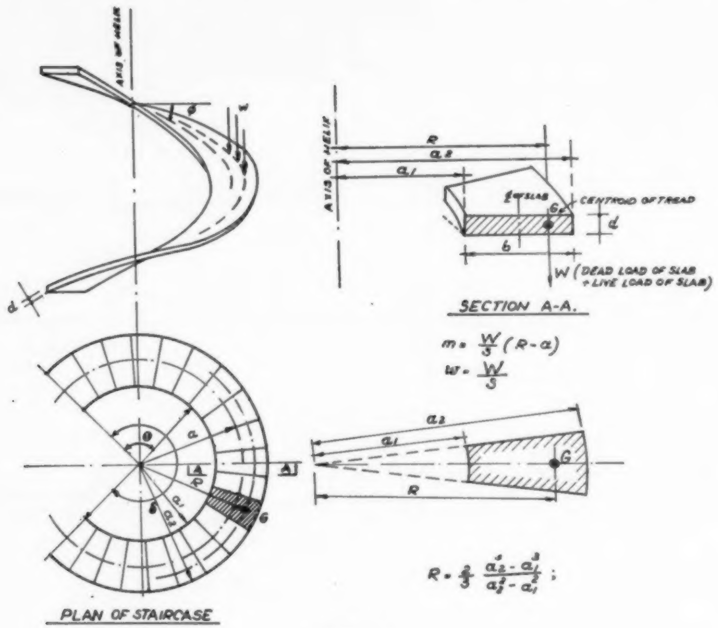


Fig. 14.

Diagrams of forces and moments are shown in *Fig.* 13. In accordance with the sign conventions shown in *Figs.* 1 to 5, the normal forces are tensile at the top and compressive at the bottom of the staircase. The bending moment about the x–x axis causes tension at the bottom face of the beam when it is negative, and the bending moment about the y–y axis causes tension at the inner face of the beam when it is positive.

The solution applies not only to the case of the staircase shown in *Fig.* 6 but also if the section is uniform, as shown in *Fig.* 14. Appropriate values of ε and σ must of course be used.

Comparison between Staircases with Both Ends Fixed and Both Ends Simply Supported.

The internal forces and bending moments for both cases are superimposed in *Fig.* 15. It is apparent that the moments differ considerably, and if full restraint occurs at the supports a more slender and economical staircase can be used.

For a large helical staircase with fixed ends, a convenient method of design is as follows. The values of the six constants for a simply-supported staircase, which are independent of the moments of inertia, are first obtained, and the torsional and bending moments at the supports are calculated. From these values the required section can be estimated, allowing for the reduction due to

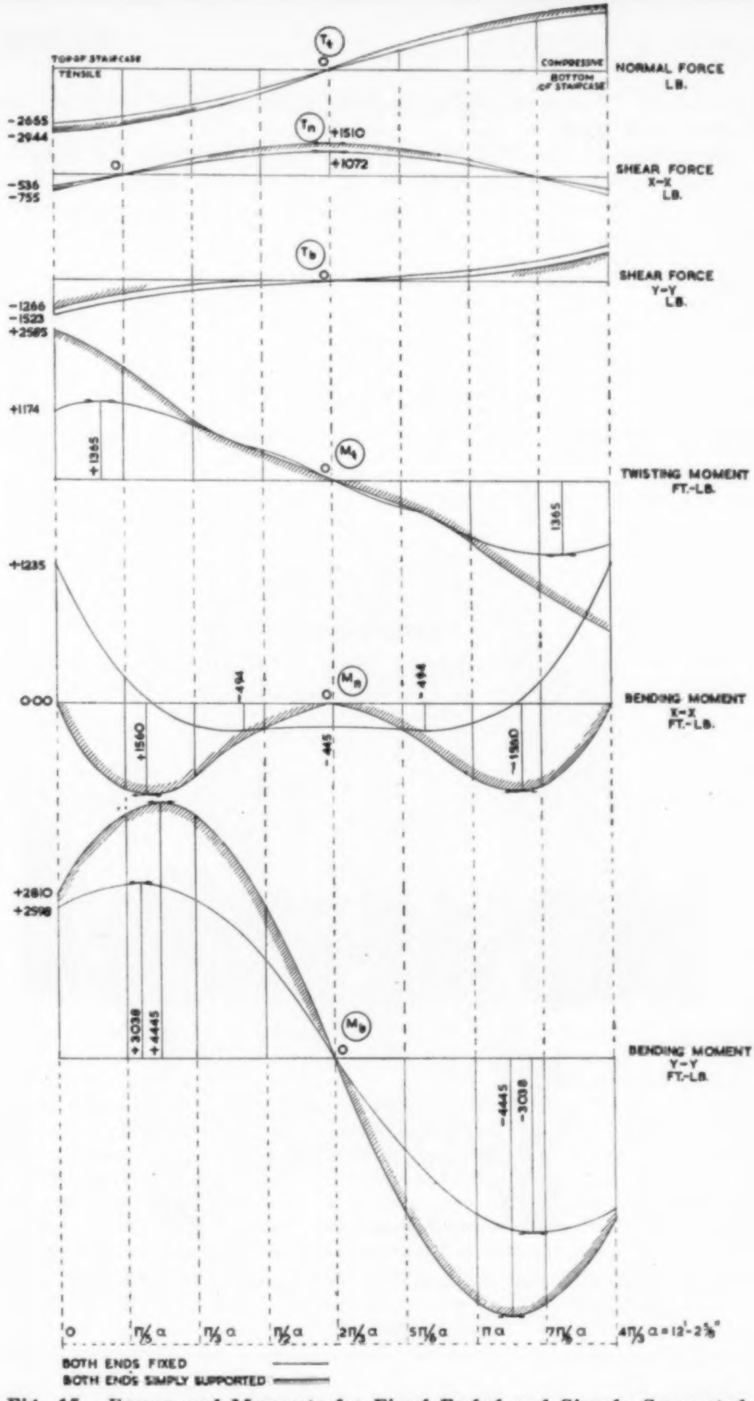


Fig. 15.—Forces and Moments for Fixed-Ended and Simply-Supported Staircases.

the fixed ends. Values of ε and σ can then be calculated and the girder designed with both ends fixed.

For smaller staircases the assumption of simple supports is conservative, and additional reinforcement can be placed at the supports to allow for the effect of fixity. In either case the use of the formulæ derived in these articles enables a rapid and exact analysis to be prepared.

(*To be concluded.*)

FIFTY YEARS AGO.

From "CONCRETE AND CONSTRUCTIONAL ENGINEERING", July-August, 1909.*

REINFORCED CONCRETE GASHOLDER.—A large gasholder recently constructed at Reick, Dresden, has a capacity of 3,300,000 cu. ft. The structure consists of three parts: a ring-shaped container and an enclosing wall both of reinforced concrete, and a steel frame domed roof and lantern. The container is constructed for a depth of water of 32 ft. 10 in. and also serves as the foundation of the enclosing wall. The thickness of the container wall at the upper part is 2 ft. The enclosure wall consists of a plinth, 24 ft. 11 in. high and 2 ft. 5 in. thick, a main wall 78 ft. 2 in. high with panels 8 in. thick, and an upper ring and cornice 30 ft. 4 in. high. The five towers with internal staircases are added chiefly for architectural reasons. They are not rigidly connected with the wall, as such a construction might cause cracking during changes of temperature.

* "Concrete and Constructional Engineering" appeared in alternate months until September, 1909.

Causes of Accidents.

On building and civil engineering works in Great Britain there are an average of about 15,000 accidents a year causing injury to men employed on the sites, and of these more than 200 are fatal. A recent number of the journal "Accidents" (published by H.M.S.O. at 1*s.* 3*d.*) gives examples of typical accidents, all of which could have been avoided. Some of these are described in the following.

Excavation.—A trench 4 ft. wide and 12 ft. deep was being dug by a mechanical excavator and the material dumped parallel to a side of the trench. It would have been easy to have placed the material well clear of the trench, but it was within a foot of the edge. The excavated material contained boulders weighing up to 1 cwt. Some of the material fell on two men in the trench and one man was killed. The risk of falls of the excavated material did not occur to the contractors. [Building Regulation No. 78 requires that material must not be placed near the edge of an excavation where it will endanger anyone below; observance of this regulation would have prevented the accident.]

Erecting Precast Slabs.—During the construction of a house two precast concrete wall slabs, each measuring about 6 ft. by 8 ft. by $3\frac{1}{2}$ in. thick, were placed 3 ft. apart and parallel to each other to form a passage. They were kept apart by two laths nailed to wooden blocks set in the top of each panel, and at the bottom they were secured by wedges and fixing-plates. A man climbed a ladder placed against one of the panels in the 3-ft. passage, his weight pushed the panel over, and this in turn pulled the other panel on to him and inflicted severe injuries. [Such slabs should always be fixed, even temporarily, so that they are capable of resisting the push from a ladder or the effect of a gust of wind. Instructions that ladders must not be placed against such slabs or that they must not be climbed until they have been fixed permanently have been proved to be inadequate.]

Compressed-Air Tools. — A com-

pressed-air tool had been turned upside down in order to insert a new spade; this had been fitted, but not locked in position, when it was ejected with considerable force and struck a man on the head. The operating trigger was on top of the handle; when the tool was turned upside down pressure on the ground depressed the trigger and the tool commenced to operate. [No adjustments should be made or cutters replaced unless the tool is disconnected from the air supply.]

COLLAPSE OF SCAFFOLD.—Two men engaged on slating a roof were working on a single-plank platform 9 in. wide supported by steel putlogs and uprights. The tapered ends of the putlogs had been driven between concrete blocks of the wall and fastened with wooden wedges. In pushing roofing felt on to the roof, the outward thrust imposed on the staging caused one of the putlogs to be pulled out of the wall and the men and the plank fell to the ground.

BARROW HOIST.—Plaster panels 8 ft. long, 2 ft. wide, and 4 in. thick and weighing about 1½ cwt. were unloaded from a lorry on to a four-wheel bogie 2 ft. 8 in. long by 16 in. wide; they were placed on edge and projected 2 ft. 8 in. beyond each end of the bogie. The hoist platform had been extended to carry the bogie and panels. The bogies were pushed on to the platform by two youths and came to rest against a timber batten nailed to the platform. A 2-in. by 2-in. batten was then placed loosely against the back wheels of the bogie. When the platform was 50 ft. above ground the bogie and panels slid off the platform, falling on to two men at the bottom of the hoist; one man was seriously injured and the other killed. [Reliance should not have been placed on a loose batten to secure a bogie.]

FRAGILE ROOFING MATERIAL.—A man working on a roof walked over some asbestos-cement sheets and fell through. [Where a scaffold is to be erected over a fragile roof covering, it is best to assume that the roof covering is not there at all.]

A British Standard Code for Earthworks.

B.S. Code of Practice No. 2003 (1959), "Earthworks" (price 25s.), has been issued by the British Standards Institution. It relates mainly to practice in Great Britain, but some of the recommendations are of more general application. The code deals with cuttings, embankments and excavations in trenches, pits, and shafts, but not tunnels, dams, dykes, canals, dredging, or river-training works. Recommendations are given for the classification of soils, the effect of weather, and the economics of earthworks in general and, with regard to cuttings and embankments, guidance is given on shallow cut-and-fill methods, compaction of soil, plant for earthworks, and the protection of earth slopes. Recommendations are also made for timbering excavations in different types of ground and for blasting.

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